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Mapping landscape change using multi-resolution remotely-sensed data, intensity analysis and trend analysis

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Abstract*:* Comparison of land-cover maps for different time steps can reveal important landscape transitions. Though land-cover categories derived by classification of satellite imagery are assumed accurate they may contain error which not only influences sizes and types of change identified, but also can mask important category dynamics. Seasonality or climate variability may be concealed in a land-cover classification generated from a particular point in time. In this paper, a spatial–temporal multi-resolution mapping approach is used to integrate trend data from Moderate Resolution Imaging Spectroradiometer (MODIS) with Landsat-derived land-cover change maps to characterize hypothetical error in land-cover change maps. Land-cover maps derived from Landsat imagery for 2000 and 2014 for two watersheds in the rural Eastern Cape of South Africa were compared to determine gross loss and gain per category for eight land-cover classes using intensity analysis in a transition matrix. Predicted change was characterized as persistence, gains and losses. Land-cover change categories and their associated hypothesized error were correlated with linear and non-linear NDVI trends. Spatial dependence was detected among the errors associated with regions of complex terrain where inherent uncertainty of land-cover classification is high due to shadow masking steep slopes. Categories indigenous forest and plantations were spectrally and phenologically more similar than others causing confusion particularly at coarser resolution. Small fragmented categories, wetlands in particular, could not be better identified using trends in the coarser resolution MODIS imagery. However, with longer time series of Landsat data now freely available, this shortcoming can be corrected.

Keywords: Land-cover change, Intensity analysis, error mapping, spatial auto-correlation, trend analysis, South Africa

1. Introduction

Land-cover data are frequently used as a proxy for mapping ecosystem ser-vices. As communication tool, maps are regarded as essential for management and decision support (Hauck et al. 2013). Change in ecosystems can generally be of seasonal nature; reflect gradual change or be abrupt, caused by disturbances in the landscape. Comparison between land-cover maps for different time steps can reveal these important landscape transitions. Though land-cover categories derived by classification of satellite imagery are assumed accurate they may contain error which not only influences sizes and types of change identified, but also can mask important category dynamics (Aldwaik and Pontius 2012). Moreover, seasonality or climate variability may be concealed in a land-cover classification generated from a particular point in time.

By using intensity analysis, a mathematical framework that systematically compares temporal changes among categories (Pontius et al. 2004), hypothetical error in the categories can be identified and the intensity of these changes measured compared to uniform (Aldwaik and Pontius 2013; 2012). Predicted change can be characterized as persistence, gains and losses. Recent research has demonstrated that classification errors reveal spatial and temporal autocorrelation concentrating error occurrences in similar regions (Burnicki et al. 2010). Anomalous patterns may provide insight into the potential processes that determine the land-cover change pattern and maps can be produced of the probability of any land transition (Pontius and Li 2010).

The Normalized Difference Vegetation Index (NDVI) (Tucker 1979) is a remotely-sensed measure of vegetation greenness and is related to structural properties of plants (Turner et al. 1999; Gamon et al. 1995) and vegetation productivity (Fensholt et al. 2004; Gamon et al. 1995). Remote sensing based time series analysis of NDVI data is therefore a powerful tool to identify land surface dynamics not only associated with seasonality and the magnitude of these dynamics can be analysed within a defined monitoring time span (Kuenzer et al. 2015; Lasaponara and Lanorte 2012). Both linear and non-linear development in NDVI can be detected (Fensholt et al. 2012). In addition, abrupt changes not associated with trend or seasonal components of the time series can be identified (Verbesselt et al. 2010). However, estimation of trends from NDVI time series data may provide substantially different results depending on the particulars of the satellite dataset, the corresponding spatiotemporal resolution, and the applied statistical method (Forkel et al. 2013).

In this paper, a spatial–temporal multi-resolution mapping approach is used to integrate trend data from Moderate Resolution Imaging Spectroradiometer (MODIS) with Landsat-derived land-cover change maps to characterize hypothetical error in land-cover change maps.

2. Methods and Results

Trend analysis was performed using the MODIS NDVI data product (MOD13Q1) on a per-pixel basis (250m X 250m). Linear development in NDVI was detected using the Pearson Product–moment linear correlation test and Theil-Sen median slope trend analysis while the Mann–Kendall monotonic test was used for non-linear development. Abrupt changes were identified using breakpoints in the trend data. Land-cover maps derived from Landsat imagery for 2000 and 2014 for two watersheds in the rural Eastern Cape of South Africa (Munch et al. 2017) were compared to determine gross loss and gain per category for eight land-cover classes using intensity analysis in a transition matrix. See Aldwaik and Pontius (2012; 2013) for more detail. If the observed intensity is greater than uniform intensity, data shows more change which is termed a hypothetical commission error, while observed intensity less than uniform intensity would represent a hypothetical omission error. Land-cover change categories and their associated hypothesized error were correlated with NDVI trends.

The accuracy of the resulting land-cover change map was 76%, determined from the accuracy of each individual land-cover map with classification accuracy of 87% for each time step. A total landscape change of almost 20% could be identified at the resolution of the land-cover classification. More than twelve percent of transitions occurred in such a way that the location of a land-cover class changed over time, while the overall quantity at landscape scale remained the same, referred to as swap. Multiple temporal resolution analysis provides additional information concerning the distances over which land-cover change occurred. At the MODIS resolution, the predicted land-cover change reduced to almost 18% with swap transitions now amounting to ten percent of the change, thereby masking smaller category changes. Possible errors in the maps influence the total land change both in terms of quantity and allocation of gains and losses.

3. Conclusions

Spatial dependence was detected among the errors associated with regions of complex terrain where inherent uncertainty of land-cover classification is high due to shadow masking steep slopes. Categories indigenous forest and plantations were spectrally and phenologically more similar than others causing confusion particularly at coarser resolution. Small fragmented categories, wetlands in particular, could not be better identified using trends in the coarser resolution MODIS imagery. However, with longer time series of Landsat data now freely available, this shortcoming can be corrected.

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References

Aldwaik, S.Z., & Pontius Jr, R.G. (2012). Intensity analysis to unify measurements of size and stationarity of land changes by interval, category, and transition. *Landscape and Urban Planning*, 106(1), 103-114.

Aldwaik, S.Z., & Pontius Jr, R.G. (2013). Map errors that could account for deviations from a uniform intensity of land change. *International Journal of Geographical Information Science*, 27(9), 1717-1739.

Burnicki, A.C., Brown, D.G., Goovaerts, P. (2010). Propagating error in land-cover-change analyses: impact of temporal dependence under increased thematic complexity. *International Journal of Geographical Information Science*, 24(7), 1043-1060.

Fensholt, R., Langanke, T., Rasmussen, K., Reenberg, A., Prince, S.D., Tucker, C., Scholes, R.J., Le, Q.B., Bondeau, A., Eastman, R., Epstein, H., Gaughan, A.E., Hellden, U., Mbow, C., Olsson, L., Paruelo, J., Schweitzer, C., Seaquist, J., Wessels, K. (2012). Greenness in semi-arid areas across the globe 1981–2007 – an Earth Observing Satellite based analysis of trends and drivers. *Remote Sensing of Environment*, 121, 144–158.

Fensholt, R., Sandholt, I., Rasmussen, M.S. (2004). Evaluation of Modis LAI, FAPAR and the relation between FAPAR and NDVI in a semi-arid environment using in situ measurements. *Remote Sensing of Environment*. 91, 490–507.

Gamon, J.A., Field, C.B., Goulden, M.L., Griffin, K.L., Hartley, E., Joel, G., Peñuelas, J., Valentini, R. (1995). Relationships between NDVI, canopy structure, and photosynthesis in three californian vegetation types. *Ecological Applications*. 5, 28–41.

Hauck, J., Görg, C., Varjopuro, R., Ratamäki, O., Maes, J., Wittmer, H., Jax, K. (2013). ''Maps have an air of authority'': Potential benefits and challenges of ecosystem service maps at different levels of decision making. *Ecosystem Services*, 4: 25–32

Münch, Z., Okoye, P.I., Gibson, L., Mantel, S. and Palmer, A. (2017). Characterizing Degradation Gradients through Land Cover Change Analysis in Rural Eastern Cape, South Africa. *Geosciences*, 7(1), p.7.

Pontius Jr, R. G., & Li, X. (2010). Land transition estimates from erroneous maps. *Journal of Land Use Science*, 5(1), 31-44.

Pontius Jr., R.G., Shusas, E., McEachern, M. (2004). Detecting important categorical land changes while accounting for persistence. *Agriculture, Ecosystems & Environment*, 101(2), 251-268.

Tucker, C.J. 1979).Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 150, 127–150.

Verbesselt, J., Hyndman, R., Newnham, G., Culvenor, D. (2010). Detecting trend and seasonal changes in satellite image time series. *Remote Sensing of Environment,* 114:106–115.